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Wind energy in Brazil: From the power sector's expansion crisis model to the favorable environment

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ABSTRACT

Since the 1970s, demands arising from the impacts of the power sector on the natural environment were added to studies regarding the strategic power sector and its impact on the economic and financial crises. Thus, the development of alternative technologies reflected the new institutional guidelines and overcame the technological paradigms that were based on increasing installed capacities. Consequently, multiple debates that consider the energy use potential of each region and its contributions to sustainable development occurred. This paper presents the information that is necessary for understanding the relationships of the development model that was founded based on waste and the expanding technologies that exploit natural resources. Actions that are aimed at developing renewable energy resources are structured based on the instability of the technological maintenance paradigm and are guaranteed by expanding technologies that were used prior to 1970. In addition, we evaluated the current institutional arrangements that are used to promote wind energy. In this case, greater attention was given to the European experience because Europe provides multiple examples of successful legal frameworks that promote wind energy. In addition, Europe is a benchmark for emerging market countries, such as Brazil.

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1. Introduction

The expansion of the Brazilian electricity market prior to 1970 was observed through its gains at an economic scale and was obtained by the development and use of technologies that ensured that the generation and transmission of equipment would steadily increase. Thus, the model was supported by

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continuously overcoming technical difficulties. In addition, the model was intrinsically related to the necessary adjustment demands of the institutional and economic models that were adopted by the nation's state economies. This paradigm assures the maintenance and institutional stability of the technology practice.

Since the 1970s, the limitations that were imposed by thoughts focused on the relationships between the energy sector activities and their impacts on the natural environment were added to the strategic aspects of the electricity sector and the impacts of the economic and financial crises experienced by the nation's states. Thus, the traditional expansion model lost momentum, which promoted the research and development of new technologies that contribute to the new institutional order and current technological paradigm [1].

In this sense, the development of so-called alternative technologies (renewable) directly reflects the new institutional guidelines and overcomes the technological paradigm that is based on increasing the expansion capacity by generating plants. Thus, discussions regarding distributed generation that consider the exploitation of each region's energy potential and its contribution to sustainable development are encouraged.

The term "sustainable development" has changed. This term is currently used by international markets as an adjustment tool that guarantees new world capitalist expansion order. This capitalist expansion order strongly differs from the aspirations of environmental movements when questioning the "development" routes. In addition, this term aims to guarantee the current and future society quality of life based on a development model that was constructed by maintaining the natural dynamics of the planet [2,3].

This paper aims to expand necessary reflection space and to understand the relationships between waste development and the need for new technologies for exploiting natural resources. This process will promote the incessant search for greater energy availability. This study is divided into six sections. Section 2 highlights the relationships between energy, development and crisis. Section 3 discusses waste economics regarding renewable energy. Section 4 discusses the exhaustion of the power sector's Expansion Model. The current institutional arrangements that are used to promote wind energy are developed in Section 5. Section 5 places more emphasis on the European experience because Europe provides multiple examples of successful legal frameworks for promoting wind energy. In addition, Europe serves as a benchmark for emerging market countries, such as Brazil. The difficulties and developments of the Brazilian wind markets are presented in Section 6. Finally, Section 7 highlights the conclusions and recommendations.

2. Energy, development and crisis

Throughout human history, energy changes have been constrained by deprivation, scarcity of raw materials, restrictions regarding access to raw material sources, and the removal of previous power structures. Hemery et al. [4] mark the first major breakthrough in the energy matrix, as described in the book of Genesis, as the moment that Adam was expelled from Paradise and condemned to the divine curse of heavy farm work. "*Cursed is the ground because of you; in pain you shall eat of it all the days of your life (…) by the sweat of your face you shall eat bread*." In this context, the mechanical energy produced by the human body is converted into a tool or machine through work.

Historically, ways to overcome obstacles of work were pursued. This pursuit established the liturgy of progress and development. In addition, this pursuit resulted in successive material production innovation. Thus, history is concerned with the continued growth performance of natural systems, increasing machine and energy system complexity, population growth and (most importantly) increased human labor productivity.

Regarding increasing labor productivity, all measured gains were closely related to improvement processes through energy systems. Technical advances in energy systems were aimed at meeting the increasing energy demands of a man while subtracting the bodily energy released by a man.

Since the implementation of the first technical innovations that were aimed at exploiting energy resources outside of the human body, increasing controlled energy has resulted in increased labor productivity. Thus, agricultural production, navigation, mechanical, and thermal energy production, and individual collective transportation processes improved.

At the end of the last century, mankind was faced with the realization that increases in technology and productivity result in decreasing energy use. Following this realization, there has been a growing need to increase the primary energy quantities that are necessary for economic system operation and for obtaining energy without increasing its availability.

From the breakdown of the technological paradigm (and well before the 1970s), humanity was faced with the challenge of redirecting its energy systems and the economic processes that overcome the irregularities observed in the historical curve of increasing energy efficiency gains with technological innovations.

In this scenario, issues related to the impacts of the development model, which was adopted at that time, began to form the international agenda, which questions the fact that this development style has always driven progress at the expense of natural resource devastation.

In addition to permanent concerns regarding the exhaustible aspects of non-renewable resources and guaranteeing free access to them, economic and energy dependence on non-renewable energy sources, mainly fossil fuels, has caused global concern regarding carbon dioxide (CO_2) emissions into the atmosphere.

In recent decades, the debate surrounding increasing global average temperatures has led to a scientific method for affirming close relationships between energy production and use (from fossil fuels) and the contribution of this energy to "global warming" as a result of increased greenhouse gas emissions.

Therefore, in this scenario of imminent non-renewable energy resource shortages, restrictions on free access to energy sources and a structured legal framework that establishes impediments and/or containment barriers for expanding use of non-renewable energy resources, renewable resource technology and usage becomes even more important.

Renewable sources point toward this set of uncertainties to ensure energy provision in a new economic development model that is environmentally sustainable and establishes emergency actions. Thus, the substitution of conventional sources should begin immediately to shorten the environmental impacts of its use.

The imperative need to create conditions that are essential for changing the energy consumption profile is also postulated. Thus, the inherent instabilities of the energy process can be minimized when conditioned with short-term changes that are caused by shortages and/or massive price increases.

However, because energy is vital for productive activities and is directly reflected in socioeconomic relations, the expansion of renewable sources follows the current goods and services production model. Thus, it is fundamentally important to understand the process of producing goods. In addition, it is important to identify potential ways for adjusting these sources to economic system functions and to the medium and long-term effects of their expanding use.

3. The victory of waste production: the renewable sources "beyond the capital"

In the last century, visible qualitative and quantitative changes were imposed for the development and function of cities. These changes significantly increased energy demands. Between the eighteenth and twentieth centuries, the world population has grown from approximately one billion people (half of the eighteenth century) to more than seven billion people in 2012 (a sixfold increase).

The development of modern capitalist societies and the rate given to this process have led to rapid growth in the supply of goods and have increased energy consumption. The consumption structure is determined by lifestyles that define family arrangement, performance and distribution levels, the possession and use of consumer goods, the distribution of equipment for heating/cooling, the transportation structure, and the housing expansion model.

The misfortunes that arise from higher energy demands and their effects are not credited to population growth or its concentration in large urban centers. The responsibility that is generated from the need for adequate functions between different energy chains is attributed to the adoption of lifestyles that are centered on the liturgy of consumption.

This current lifestyle has increased and concentrated the demands for goods through more widespread use of home appliances, private transport, and the incessant appeal of wasteful consumption. In addition, new demands are generated without extending the marginal utility of these demands. In microeconomics, utility is understood as the level of satisfaction a person obtains from consuming a good or performing an activity. Marginal utility measures the additional satisfaction that is obtained by using an additional quantity of goods.

In this context, it appears that increasing production, which is a result of civilizing potential that arises from advances in science and technology, becomes distorted with the adoption and consolidation of destructive and wasteful capitalistic practices. Thus, natural needs (under the pressure of a required commodity production increase) are constantly replaced by "historically created needs."

The search for "new" products can result in products becoming obsolete before the end of their service life. Generally, large-scale production and competition causes goods to become less durable. Thus, a new product can be acquired more cheaply than continuing to reuse an old product.

Even without reduced utility, an item becomes "obsolete" when its production process is improved or when the product is no longer in the current consumption pattern. Thus, the "discarded" articles are accessible to a portion of society that did not initially have the purchasing power to acquire these articles. The process generates a new continuously fed demand without increasing the marginal utility of the goods.

Increasing productivity is not unpopular but rather desirable within certain standards. However, it is difficult to balance the "society of disposable" (optimum between production and consumption).

Currently, the use of renewable resources as an alternative energy source is advocated. However, in a society based on wasteful consumption and on decreasing marginal utility of goods, the most efficient reuse of natural resources is preferentially arranged in elaborate efforts to reduce wasteful production.

According to its defenders, the exploitation of renewable resources as an energy source should be focused on developing clean and abundant sources. In this sense, Illich [5] warns that (with the current consumption patterns) increasing the volume of energy produced from renewable sources is intrinsically linked with the continued expansion of social differences.

Thus, we must be aware that the adoption of clean energy production will not eliminate the energy-environmental crisis in the world agenda. The encouragement of greater participation may result in a race for clean energy production to justify the status quo of production and consumption patterns. In this context, Illich [5] ponders

> "*Environmentalists are right in saying that all not-metabolic energy is polluter: it is now necessary that politicians recognize that the physical energy, when certain limits are exceeded, becomes inevitably corrupter of the social environment. Even if we could produce a non-polluting energy and produce it in large quantity, the massive use of energy will have, on the social body, the same effect as the intoxication produced by a drug physically harmless, but psychically enslaving.*"

4. The exhaustion of the power sector's expansion model

In the 1970s, early signs indicated that a successful expansion pattern was occurring in the electricity sector. These signs were based on expressive exploitation at an economic scale and scope through large investments. During this period, different settings showed restrictions for expanding the model by force. These traits included (i) technological limitations, (ii) political and economic instabilities, and (iii) environmental pressures.

4.1. Technological restrictions

Thermoelectricity is the dominant electricity generation technology in the world. This finding results from the absence of a worldwide, uniformly distributed and nontransferable water potential. This process differs from the processes that use fossil fuels because fossil fuels can be transported in crude or processed forms to any market. This condition allows the dissemination of thermoelectricity on all continents, especially in areas where the availability of water resources is negligible or nonexistent.

Thermoelectric technology is consistently growing. Consequently, its installed capacity has increased due to technology development and the use of materials that allow greater performance and efficiency gains. However, the rates of gain for thermal performances in steam turbine generation units began to show signs of exhaustion toward the beginning of the 1970s.

Bicalho [1] shows that this exhaustion was related to the unsatisfactory performance of new materials that were developed to permit the operation of generating units at higher temperatures and pressures. As a result of using these new materials, it was found that the generation units began to exhibit deformation and corrosion problems. These problems caused the availability levels of these plants (plants operating between 560 °C and 5,700 °C with a recorded availability coefficient of 0.88) to report values that were lower than those recorded in the plants that used technologies from the 1950s (plants operating between 480 °C and 5,100 °C with a recorded availability coefficient of 0.91).

In addition, the costs that were added by the performance gains from the new materials (superalloys with a high content of nickel, cobalt and magnesium) overcame the operational gains that were measured by the increased performance. Thus, a paradox was established in which the limitations of the metallurgical industry were used to condition technological advances in the thermoelectric industry. Increasing the thermal performance from 38 to 39% increased the cost by US$ 3/kWh in 1957. When the same performance increased from 39 to 40%, the cost jumped to US$5/kWh. The costs projection for increasing the thermal performance by more than one unit was estimated at US$ 12 kWh (ISLÃ Sampério apud Bicalho [1]).

Expanding the installed capacity of the higher performing generating units increased the complexity of the systems operation. This complexity was attributed to greater plant vulnerability to failures, which determines the existence of a widespread maintenance program and contributes to rising costs and reduces the plant's availability coefficient.

Regarding the expansion of hydroelectric developments, no severe technological restrictions occurred from expansion. The factors that determine the size and installed capacity of this technology are limited by the potential exploration of the sites and their economic and environmental limitations, which are determined by the diffusion promoter. However, this technology cannot escape the expansionary paradigm crisis of the electric power generation market. This technology suffered various restrictions that were imposed on market expansion in the 1970s and beyond.

4.2. Political and economic implications

In the 1970s, increasing oil prices marked the end of a period of steady supply expansion in the history of energy economics. A new era advocated the end of oil abundance.

Oil shock is a direct result of energy supply at a low price and was recorded in the three decades preceding the crisis. Oil shock reveals itself as a balance of world financial, political and economic situations. Therefore, the crisis indicated the rupture of the expanding hydrocarbon market on which the entire capitalist reproduction basis was formed (i.e., ensuring stability in storage of this fuel).

Oil monopolies succeeded in continuously reducing the reference price of oil for more than 20 years. This reduction was linked to a continuous reduction of payment rates due to the exporting countries. Regarding the maintenance of this exploitation structure, Hémery et al. [4] said

> "*The constant threat of economic reprisals or military coups was enough to maintain very low levels of fees and charges imposed by producing countries. The oligopolistic organization of the market imposed its laws*."

In the early 1970s, the major oil companies decided to reduce their investment in exploitation to maintain prices and to restrict competition. This reduction led to the destabilization of the world oil market.

According to Hemery et al. [4], in the second half of 1973, conditions were necessary to interrupt the growing oil supply at low prices, including (i) an increasing demand in industrialized countries; (ii) reduced safety margins for production, which becomes a barrier to sudden demand increases; and (iii) political instabilities observed in the Middle East.

During the five years after the 1973 brutal price hike, prices were relatively stable in the international oil market. However, in the second half of 1978, this apparently stabile and regular price suddenly changed. With the victory of the Iranian revolution, whose first act was to cut production by 2.7 million barrels/day, oil-importing countries were frightened that the conflict would be extended throughout the Middle East. Thus, countries tried to set policies that would create stock.

In eight months, the world oil market transitioned from a supply excess situation to a supply shortage situation. The price per barrel increased by approximately two and one-half times on the parallel market, which resulted in many reference price increases during 1979. At the end of the year, prices reached US$ 40.00 on the Rotterdam spot market. Simultaneously, the official price set by OPEC was US$ 24.00/barrel, compared with prices of US$ 12.58/barrel and US$ 12.70/barrel in October 1978 [6].

Regarding the development of new generation technologies, increasing oil prices were a milestone regarding the awareness of the national dependence on oil and the prospect of exhausting this resource endangered operation stability because increasing oil prices were reflected in their balance of payments. In developing countries, increasing oil prices resulted in increasing prices for goods and services, which agreed with trends in industrialized capitalist countries.

Once the capitalist productive machine needed to keep running, it was imperative that the global dependency on oil be reduced. Thus, it was necessary to open new markets to disseminate new consumption habits and to search for new developing technologies, which would enable the maintenance of existing needs and the search for bio-fuels, solar and wind energies.

In the 'post-crisis' period, a search for energy rationalization through changes in consumption habits, the adoption of more efficient equipment and the substitution of oil by other sources occurred.

Previously, thermoelectric power had benefited from the long period of low oil prices. Now, the thermoelectric power generation in the world faced a situation in which its increasing costs led industries to migrate and expand to the use of coal technology. In addition, this change resulted in the use of hydroelectricity and supported the nuclear industry. Parallel to this global energy sector movement, the so-called "renewable energy sources" were debated regarding energy supply expansion routes and its storage.

In Brazil, the impact of the oil crisis led the government to consider the energy issue as a top priority. In 1979, the National Energy Commission was created to define actions that would ensure rational energy use, increase the domestic supply of oil by reducing the volume of imports from this source, and substitute the use of derivatives for other energy sources and/or for adopting new technologies.

The main guidelines presented by the National Energy Commission are summarized as follows according to Santos [6].

- In Brazil, the generation of electricity shall not depend on oil because the national hydro potential will be exploited at its maximum possible level. When the hydro potential is exhausted, nuclear energy shall be used.
- The vulnerability of national energy results from liquid fuels, and their reduction will be achieved by substituting imported oil for national oil.
- We shall imperatively seek sources to substitute petroleum derivatives.
- Energy conservation shall be a goal, especially regarding imported fuels.

As expected, Brazil's massive water resource potential became a reference in the expansion of the power sector, which also served as a substitute source for oil. Consequently, the use of electricity and the metro-transportation networks in large cities were expanded and a national program of nuclear energy use was outlined.

Regarding renewable energy, the development of these technologies was quick, focused on the academic and demonstrative levels, and did not achieve commercial scales (except for the National Alcohol Program, Pro-Alcohol, which was created in 1975). These changes highlighted Brazil in the development of renewable sources for oil derivative substitutes through the direct use of alcohol and its addition to gasoline. Between 1983 and 1986, the percentage of alcohol-fueled cars in Brazilian production reached its peak of between 73 and 76%.

From 1975 to 2000, Pro-Alcohol boosted the production of approximately 6 million vehicles powered exclusively by

hydrated alcohol. This program also enabled the substitution of gasoline for ethanol at up to 25%, which eliminated the emissions of approximately 400 million tons of CO_2 into the atmosphere. In addition, the use of hydrated alcohol eliminated the country's need to import approximately 550 million barrels of oil, which saved the country approximately US$ 11.5 billion.

Between 1980 and 1990, significant changes occurred at a global macroeconomic scale. In the two previous decades, inflation increased in developed countries. In the 1980s, interest rates increased in foreign markets, which reduced capital and made it difficult to attract international resources and thereby further promoting inflation.

Increasing inflationary processes resulted in increasing expansion costs for generating parks. In addition, because the energy sector was being used as a tool to help control inflation, only a very small portion of the increasing costs was passed on to tariffs. Thus, the tariff rate moved away from the actual values. This inability to pass on costs began to make the expansion of generator parks impractical for large enterprises and greatly disrupted the observed electricity sector's expansionary trends.

4.3. Environmental demands

The ability of environmental variables to influence the decision making process varies in its importance with the degree of political and socio-economic development in each country. However, international pressure aimed at adopting environmental parameters in the development process of socioeconomically disadvantaged areas has standardized the debate around the issue of the environmental impacts of economic development.

Recent international vigilance regarding the pressure that economic development has on the environment, as well as controlling these effects to safeguard medium and long-term environmental sustainability (focused on energy production), is needed.

The stressed evidence given to the energy sector as it relates to the impact of its expansion through conventional technologies is perfectly justifiable. The end use of the different energy products offered in the market is strongly related to the economy, industry, transport, service and residential sector drivers.

Therefore, the development of these economic sectors is important for economic expansion. In turn, these sectors urgently need an energy supply system with easy access and high-level storage security. Then, the greater weight of the listed environmental impacts of undoubted social and economic importance will rest on the system function, which is heavily dependent on the use of non-renewable primary energy resources and is subject to progressive exhaustion [7].

In this scenario, numerous environmental restrictions were structured based on the regulation of power sector expansion because this sector significantly participates in the world energy production and consumption structure.

5. Institutional and regulatory promoters are instruments of wind-electric technology

Renewable energy sources have (as a materialization field) an energy market that is dictated by the constraints of the fossil fuel world market. This market is structured in a distorted way because the prices of these fuels do not reflect their costs. These distortions occur because the external costs that are associated with the use of these fossil fuels are not internalized in the final price of the fuel. These costs include the environmental impacts, the impacts on population health and crops, and the social arrangement interferences that are attributed to the fossil fuel energy chain.

Therefore, to encourage the expansion and use of renewable resources at their national potential, the strict logic of the word "market" must be imperatively flexible. The issues of cost should be discussed more broadly and in detail to enable a deeper study to assess the upstream and downstream consequences of the expansion of renewable sources [8]. Because of this concern, the European Commission [9] stated the following in its Green Papers:

> "*We must avoid that the demand for immediate return on investment in an open market come at the expense of investment in sectors with intensive use of capital or whose profitability is not necessarily guaranteed in the short term, such as renewable energy*."

Accordingly, renewable energy sources are presented as feasible alternatives for providing electricity to the national states in their search for stability. The rational development and use of national renewable energy reserves depends on heavy political and economic efforts that are directed by the State through regulatory and institutional instruments and by the adoption (by the productive sector) of actions that overcome historical logic. This development led to the planning of the power sector expansion with non-renewable fuels rather than with the national renewable resource reserves, which ensured the sustainability of the renewable energy market.

Multiple regulatory instruments and institutional arrangements are structured in different regions of the world. These arrangements aim to develop and affirm a stable renewable energy market. An international consensus exists that renewable energy is not highly competitive with conventional electricity generation technologies.

According to Guerra [8], to clearly define and comprehend this contradiction "would be worth only the ontogenesis of the problem, because the major fault is related to the full and unrestrained assumption of the market buzzword." The production costs of renewable technologies are relatively high. Thus, the strict market vision does not allow renewable technologies to compete under the same commercial conditions in which older technologies are dominant, such as power plants, natural gas combined cycle thermometric plants, and electronuclear units.

Thus, the increased participation of renewable resources remains tied to evaluations that are intrinsic to the term "market". In this sense, Guerra [8] notes that

> "*the word market took a revolutionary character when turned into something tangible, alive, part of everyday society, no longer merely explanatory, conceptualist. It started to happen when referring to elaborate schemes of Project Finance, whose ultimate goal is to leverage the resources available to a competitive activity, by pricing immediate consumer goods through rates and prices that remunerate the investors-agents quickly and effectively, providing reliable returns*."

These rates and prices may only be improved by mechanisms that overcome any logical training. This logical training is different from that previously incurred for achieving profits based on sophisticated elaborations of the Internal Rate of Return (IRR) [8].

The electricity market in which renewable sources should compete is distorted because the determined fossil fuel prices do not reflect all of the supply chain costs. This distortion greatly widens when considering the fact that the external costs associated with the exploration, transportation and use of fossil fuels are not internalized when the prices are defined. These costs include environmental damage, individual and collective health impacts, and social arrangement interferences, which are attributed to the fossil fuel energy chain and other conventional

technologies, such as large hydro and nuclear power plants that do not internalize their social and environmental costs [10].

The liberalization of the electricity market is conducted by promoting gains to the final consumer. These gains may be reported as the quality of supplied energy and/or the reduction of final prices. These gains are formed in a scenario in which developments are already amortized. The power plants that were developed prior to market opening do not compute their past and future environmental costs. Thus, these power plants compete asymmetrically with new technologies that use renewable resources and have environmental appeal that justifies this assumption [11].

In the liberalized markets, market agents that have been established for over a century disagree with new producers who use clean technologies with decentralized operations. However, this dispute has not dampened their investments and does not consider the environmental gains promoted by these markets [11].

The European Union identified an alternative for these distortions in a liberalized market. This alternative was opposite of that used for renewable technologies and was established as a regulatory and institutional instrument to enable the sustainability of competitive markets. However, this alternative also assures the development of renewable technologies.

Accordingly, the European Commission shows that renewable energy may be incorporated into the continents energy matrix to strengthen the security of its energy supply. The European Commission explains that the development of renewable energy depends on the establishment of effective political efforts and economic interventions. In the present circumstances, the Commission considers that renewable energy is the only source of energy that the EU has that provides some flexibility for increasing the energy supply [12].

The European Commission [12] recognizes that the main barrier for expanding renewable sources, especially wind power, is financial. Thus, the European Commission states the following:

> *"We must recognize that some renewable energy sources require large initial investments. One of the possibilities for financing of renewable energy to explore could be the subject of the most profitable sources of energy—nuclear energy, oil and gas—to a form of contribution to the development of renewable energy."*

The European Commission's proposal conforms to other current practices and intentions regarding the world's promotion of renewable energy. By stating that barriers to the dissemination of renewable technologies is a problem to be solved with the establishment of subsidies, in addition to national, regional and local regulation [12], the European Commission strengthens research centers, NGOs, environmental agencies, the productive sector and other actors that are involved in the development and promotion of renewable resources and sustainable development. According to the Commission [12], such interventions must be included in a range of decisions, from investigation or funding aids to drastic fiscal measures that are in favor of renewable energy or purchase obligations. These interventions are included by electricity producers and distributers and consider the minimum percentage of electricity that is produced from renewable energy.

5.1. Support mechanisms for promoting renewable energy

Many legal instruments that aim to expand renewable energy technology participation globally have been used in the past two decades. Many countries use peculiar alternative instruments within their political debates that lead to the implementation of reforms in the electricity sector.

The set of adopted policies that aim to expand the share of renewable energy that is used within the electricity market can be classified as either legislative or non-legislative. These legislative instruments refer to interventions that are directly conducted by institutions and/or representatives of state power authority. The non-legislative instruments are promoted by any actor that is interested in developing these technologies.

Within the non-legislative interventions, marketing actions of 'green energy' that are managed by market agents (generators and distributors) are included. For example, the conversion of conventional generation plants to environmentally friendly units is encouraged. In this way, companies offer electricity from renewable sources and receive a bonus from a 'green tariff' that is voluntarily paid by consumers [13]. In addition, market players set goals to leverage renewable technologies and make them mandatory.

For Nascimento [14], this type of mechanism transcends that of giving the consumer and/or production and distribution agents freedom of choice (either Traditional Energy or Green Energy). This choice provides construction and financial diversity among the agents and releases them from financial obligation. Therefore, this mechanism reduces environmental damage and is promoted by the electricity production sector without price of energy commodity interferences.

The legislative incentives focus on demand and control instruments (regulatory instruments) and on market-based instruments (economic instruments). Control instruments constrain the market player actions with laws and regulations. These regulations aim to provide a framework for socioeconomic and environmental standards that are set by society through its legal representatives (the State).

The adoption of limits regarding annual CO_2 or greenhouse gas emissions, the adoption of stricter rules regarding operation specifications in generation plants, and the adoption of gradual electronuclear unit discontinuation programs are very significantly control instruments that have been adopted in the energy sector around the world.

Economic instruments that directly affect the functional structure of the economic system are used in various ways (e.g., by introducing taxes or other fees and by providing financial support).

Among the policy instruments that are used to promote renewable technologies for energy production, the economic instrument set is the most important. Economic instruments are divided to promote increased supply through price regulation or the use of quotas.

When determining the differences that occur between these mechanisms, basic assumptions are made based on the ways these instruments influence, modify or eliminate certain market behaviors. The price regulation instruments act by establishing market prices for "green" power or by absorbing production costs. Compensation mechanisms for the supply network (for example, the Feed-in Tariffs mechanism, which subsidizes investments and adopts certain tax advantages) are an example of price regulation interventions. A basic feature of this compensation mechanism for the supply network is the growth of new production units. In addition, the volume of "green energy" that is generated results from free market operation and cannot be defined [15].

In the model of adopted quotas, "green energy" demand is fixed and market agents are required to comply with their allocated percentages. In these models, the market price for "green electricity" is variable and is subject to market mechanisms.

In addition, the price regulation instrument can be grouped into new investment and production incentives. Incentives that promote new investments include direct subsidies, tax breaks, and accelerated depreciation. These incentives can result in a significant number of new generating plants. In addition, a strong

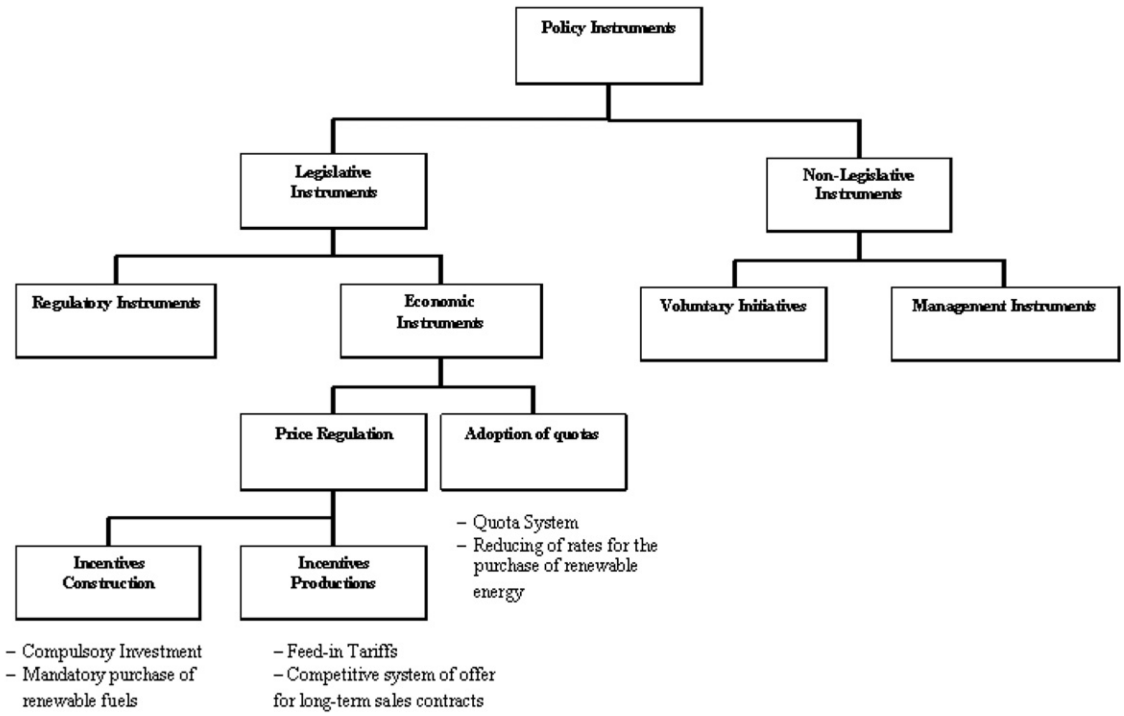


Fig. 1. Regulatory and institutional instruments.
Source: Elaborated from Enzensberger [15].

focus on increasing the installed capacity of renewable energy can potentially contribute to the adoption of inefficient enterprises. Moreover, production incentives aim to develop efficient projects that produce "green energy" with the support of the involved capital.

The Feed-in Tariffs instrument is widely used within to promote renewable technologies, and it is considered to be responsible for the rapid expansion of renewable resources in Europe (mainly the Aeolian-electric technology in Spain, Germany and Denmark).

In this mechanism, the purchase of electricity that was produced from renewable sources is mandatory. Thus, electric utility companies are obliged by law to acquire energy from companies that use renewable energy for a certain price and to deliver this energy to the final consumer. The value of these rates can be obtained from the percentage of the price that is paid by the residential sector. This price is an absolute value that is defined according to the basic costs of the technology or according to the generation costs that were avoided by excluding the use of conventional sources [11,15,16].

The Supply System Tender system is a modified version of the Feed-in Tariff model. In this model, a bid is made for a long-term renewable power supply contract, from which the market shares of each technology are determined. The winners are selected based on their submitted cost plan and receive a guaranteed fixed price (per kWh) throughout the contract period. The trading price of energy from each technology is determined by referencing the costs of the final selected bidder [16].

In the Quota System of Renewable Portfolio Standards (RPS), a certain percentage of the renewable technology contribution share in electricity production is set by government agents through legal mechanisms. These constraints require electricity distribution companies and other recognized actors in the electrical chain to take responsibility for achieving the established goals.

Producers receive a "green" certificate, which corresponds to the amount of electricity that is generated from renewable resources. To ensure certain flexibility in the quota system and to ensure that the objectives are actually achieved, this arrangement can be combined with a 'green electricity' certificate training system called the Certificates Trading Model. The credits generated by these certificates should reflect the environmental benefits that are promoted by "green electricity" and can generate additional income and fulfill the established quota once traded.

Because market players are forced to comply with an allotted renewable energy share, they may choose to build their own plants to receive energy production certificates. In addition, the market players can purchase green power from independent plants and add that energy to their certificates. Furthermore, market players can purchase certificates without physically acquiring the generated energy, which finances the implementation of new renewable energy production units elsewhere [13,15].

The objective of the Certificates Trading Model (certificates of "green energy") is to establish competitive conditions for renewable technologies in the electricity market. Green certificates were first introduced in the form of voluntary memberships, which allowed "green electricity" producers to be rewarded for the difference between conventional electricity and electricity generated by renewable resources. This scheme focuses on the voluntary choices of consumers who will choose a higher rate in exchange for promoting clean electricity production.

When green energy certificates are traded within the quota system, significant price fluctuations occur. When renewable energy is scarce, the certificate prices are high; however, when renewable energy is in excess, their prices fall [16].

Fig. 1 provides an overview of the main Regulatory and Institutional Instruments that were used in the promotion of renewable resources technologies for energy production. These instruments were previously described by Enzensberger [15].

5.2. *Brazilian institutional support for renewable sources promotion*

The Incentive Program for Alternative Sources of Energy (PROINFA) and the Energy Development Account (CDE) were both created by Law 10,438 of April 26th, 2002 and amended by Law 10,762 on November 11th, 2003. This law aimed to share the

electric energy produced from wind, small hydro power plants (SHP) and biomass projects. PROINFA is the legal reference for all government actions that are directed toward renewable energy developments in Brazil. In its first stage, 3300 MW of power were equally distributed among the sources.

Law 10,762 (2003) promoted changes in PROINFA. The guaranteed purchase of electricity that was generated in the program was changed from 15 to 20 years through contracts with ELETROBRAS until the end of April 2004 for facilities that began operation by December 2006.

The initial deployment of 3300 MW of power was expected to be equally distributed regarding the installed capacity of each source that participated in the program. The purchased power was defined by the economic value that corresponded to the specific technologies of each source. The economic values that corresponded to specific source technologies referred to the amount of electricity sales. These sales had a certain level of efficiency, which made midlevel projects economically viable when using the referred source.

The cost of electricity purchased by ELETROBRAS under PROINFA was prorated among all classes for the final consumers. However, the consumers that belonged to the low-income residential subclass (defined as those with monthly consumptions of less than or equal to 80 kWh/month as determined by the National Interconnected System[1]) were charged in proportion to their verified individual consumption. Once installed 3,300 MW, the PROINFA promoted a second stage considering that renewable energies should be responsible for 10% of all electricity generation in Brazil until 20 years.

For the second stage of PROINFA, Law 10,762 (2003) increased the timeframe in which contracts needed to be signed with ELETROBRAS to 20 years (initially, Law 10,436 (2002) provided a term of 15 years).

PROINFA strengthened the Brazilian institutional option for supporting renewable energy development through a Feed-in Tariff System. This model defines a price for electricity produced from renewable sources, and the quantities of electricity that are offered are regulated by the market. Porto [17] asserts this option by stating the following:

> "*the mechanisms existing in Law 10,438 (PROINFA) are compliant with recent success practices in several countries, such as Germany, Spain, Denmark, and France, among others.*" *(all of the countries cited adopt the* '*Feed-in tariffs*'.

Decree 5,025 in 2004 stipulated that the capacity for contracted wind contracts within the first PROINFA phase could not exceed 220 MW in each State (20% of the Aeolian-electric power to be hired in PROINFA). In this sense, the mechanisms and arrangements that were adopted by the Brazilian government and its assumptions created alternatives that could enable the decentralized development of Aeolian-electric technology. In theory, the potential of forming investment conditions for wind energy on un-configured sites was excellent. This guidance conforms to a public policy objective that will be exploited by forming a national development project and by adopting new technologies, which is the case with PROINFA.

Table 1
List of wind projects in Brazil PROINFA.
Source: Salina [18].

Plant	State	Hired Pot. (MW)
Agua Doce	SC	9
Canoa Quebrada	CE	57
Pirauá	PE	4.25
Praias do Parajuru	CE	28.8
Praia do Morgado	CE	28.8
Volta do Rio	CE	42
dos Índios	RS	50
Sangradouro	RS	50
Osório	RS	50
Enacel	CE	31.5
RN 15 - Rio do Fogo	RN	49.3
Beberibe	CE	25.2
Salto	SC	30
Púlpito	SC	30
Elebras Cidreira	RS	70
Alhandra	PB	0.35
Alhandra	PB	5.05
Rio do Ouro	SC	30
Campo Belo	SC	9.6
Amparo	SC	21.4
Aquibatã	SC	30
Bom Jardim	SC	30
Cruz Alta	SC	30
Millenium	PB	10.2
Albatroz	PB	4.5
Coelhos II	PB	4.5
Camurim	PB	4.5
Coelhos IV	PB	4.5
Presidente	PB	4.5
Coelhos III	PB	4.5
Atlântica	PB	4.5
Mataraca	PB	4.5
Coelhos I	PB	4.5
Caravela	PB	4.5
Formosa	CE	6.6
Formosa	CE	5.4
Formosa	CE	13.8
Gargaú	RJ	28.05
Pedra do Sal	PI	17.85
Mandacaru	PE	4.25
Xavante	PE	4.25
Gravatá Fruitrade	PE	4.25
Vitória	PB	4.25
Santa Maria	PE	4.25
Quintanilha Machado I	RJ	135
Foz do Rio Choró	CE	25.2
Alegria II	RN	64.5
Cascata	SC	4.8
Santo Antônio	SC	1.93
Palmares	RS	7.562

Table 1 presents a list of wind projects in Brazil (by State) and provides their respective power contract by 2010 under PROINFA.

The wind projects under PROINFA need to be adjusted due to recurring operational start delays, as reflected in the difficulties that are experienced when implementing the program. These difficulties result from the innovative character of PROINFA and are a mirror of the Brazilian socio-economic situation and its risks and uncertainties, which are seen by investors.

As a sectoral planning instrument, the Brazilian government recently adopted an auction system for the expansion of large hydro-plants and biomass, wind, SHPs and biodiesel plants. The auction system calls for efficient processes, site selection, technology exploration and wind farm contract supplies. A key factor in the use of auctions is that it makes the process more transparent for society. In addition, this process results in fair prices, which are necessary to encourage the participation of potential bidders and to prevent collusion.

[1] The National Interconnected System (SNI) consists of 96.6% of Brazil's electricity production capacity and is composed of generating units in the south, southeast, midwest, northeast and north. The remaining 3.4% of the electricity production capacity not contemplated by SNI is concentrated in small isolated systems, mainly in the Amazon region. In addition, the domestic supply of electricity in 2010 was 548 TWh. This electricity was predominantly produced from water. Hydroelectricity was responsible for approximately 74.9% of the supply, and wind power was responsible for approximatly 0.4% of the domestic energy supply.

In the Brazilian auction system, the lowest rated criterion is used to define the winners. Thus, the winners are those who offer electricity at the lowest price per MWh to meet the anticipated demand. The most common auction model is the German Auction Model (price descending) in which a certain fixed volume of MW is auctioned. However, in this model, buyers can choose the desired fraction to offer.

The bids offered in recent energy auctions are surprising the wind energy market in Brazil. The winning auction bids are currently declining and reaching substantial discounts relative to the price ceiling that was set by regulators. The values of these bids reached US$ 76.50, 65 and 56.25[2] in 2009, 2010 and 2011, respectively.

Wind energy that is currently produced in Brazil is among the cheapest in the world (below US$ 60/MWh). In the U.S., wind energy, at best, reaches a price of between US$ 85 and 107 per MWh. From 2009 to 2011, the government hired approximately 3 GW of wind power through auctions for the next five years. It is hypothesized that the prices have reached a limit and that companies have introduced a new level.

Among the arguments that justify this new level, the economic crisis that is affecting the US and Europe requires new strategies for expanding the market for manufacturing equipment. In the short term, the American and European markets will not reestablish their original volume of industrial orders.

Pereira et al. [19] emphasized that the continuous price drop in the auctions resulted from the permanence of the government tax cut strategy (approximately 30% of investment); the high park bid capacity factor; the site locations (smaller distances from the electricity grid reduce transmission costs and electricity losses); the most suitable sites (which reduce the costs of civil structures and transportation of the purchased equipment to the location); commercialized carbon credits; favorable financing conditions for the National Bank of Economic and Social Development (BNDES); auctions exclusively for wind energy (which enable scale); intensification of internal competition in view of the imminent wind energy market consolidation; the rising actual cost against the dollar (which reduces the cost of imports and results in future increasing revenue); and the decreasing energy of new wind sites in developed countries. Thus, the over-supply of equipment occurs in countries that have emerged from this crisis faster than Brazil.

Pereira et al. [19] indicated that the recent expansion of wind energy in Brazil has enabled numerous gains associated with cost reduction, supply expansion (without incurring greenhouse gas emissions), diversification of sources and technological learning. In addition, these authors underlined the interests of several multinational companies within the country and allowed the manufacturing and/or assembly of equipment and services with a higher added value. This process created jobs and encouraged universities and technical schools to incorporate wind energy courses.

The decentralization issue of energy resource use is often underestimated. However, decentralization is an interesting way to promote the local development of previously stagnant municipalities. Increasing tax collection by using wind sites has enabled progress regarding the economic dynamics of cities and has increased investments in infrastructure. This redistribution of energy resource uses indicates that extra income is partitioned differently and is associated with more limited social and environmental impacts in comparison with thermal options.

6. Wind market in Brazil: difficulties and developments

There are a number of factors that influenced the observed implementation and expansion of renewable energy resources in Brazil. The use of wind energy is more recent and will likely be consolidated to achieve as much success as ethanol production. In 2011, Brazil was the second largest ethanol producer (behind the USA) with a production of 25 billion liters. Similarly, the exploitation of hydroelectricity was consolidated, and more recently, efforts were made to promote biodiesel. Thus, Brazil is ranked fourth in biodiesel production.

Brazil has a historical tradition of generating electricity with hydroelectric plants. Approximately 84% of Brazil's energy comes from hydropower. Biomass and wind power contributed 5.5% and 0.3% of the domestic energy supply in 2010, respectively [20].

Brazil has more wind power facilities than any other Latin American country. However, wind energy and hydropower complement each other. Although periods of low rainfall occur in the south/southeast regions of Brazil, the northeast region has adequate wind that allows for expansion. According to Global Wind [21], Brazil's potential is enhanced by its increasing energy demand and its strong industrial base. These factors allow Brazil to be a regional leader in wind generation. In August 2012, data indicated that Brazil has reached a milestone of 2 GW of installed wind generation. Furthermore, additional generations of 7 and 16 GW are expected to develop by 2016 and 2021, respectively.

Despite the trend and future prospect of continued renewable energy success in Brazil, recently, several barriers for promoting renewable sources were encountered. In particular, wind energy shows how these barriers were developed and highlights the instruments that were actually applied in Brazil.

The lack of political support for new ideas in the energy field is one point that can prevent the development of renewable energy. In Brazil, the wind energy strategy was used to ensure the supply of electricity through a specific auction (PROINFA), which guaranteed a price above that of the market and allowed the penetration of technology and a return on investment when the technology was in its pre-commercial stage. Later, we performed various energy auctions for wind, which significantly expanded Brazil's installed capacity. The strategy for structuring the wind energy market through public auctions ensured the participation of the local content and encouraged domestic industry. However, despite the need for improvements, this strategy improved competition between the sources and between the producers. Thus, incentives such as auctions and PROINFA specific wind power created a favorable environment for wind to become competitive in energy auctions. Fig. 2 indicated that the price of wind energy was reduced by 60% following the first PROINFA auction A-3 in 2011. Thus, Brazil has the lowest wind energy price in Latin America. A lack of appropriate long-term financing is another point barrier in the market consolidation of renewable sources. The lenders' aversion to risk is high because renewable energies have high production costs. Thus, when the market is not well established, the technology is not widespread and the scale of production is reduced. Therefore, it is important to overcome several barriers and legal policies so that lenders feel more comfortable with supporting renewable energy [23]. Regarding financing, the Bank of Economic and Social Development (BNDES) is the main agency that finances large wind projects. BNDES has a line of credit for bioelectricity, biodiesel, ethanol, wind, solar, small hydroelectric and other energy alternatives. Thus, BNDES funding companies between 6.4–10.58% per annum, considering credit risk profile of the applicant. The maximum contribution from BNDES is 80%; however, this contribution may be expanded by up to 10% and is limited to 90%. The repayment term is up to 16 years, and

[2] Pereira et al. [19].

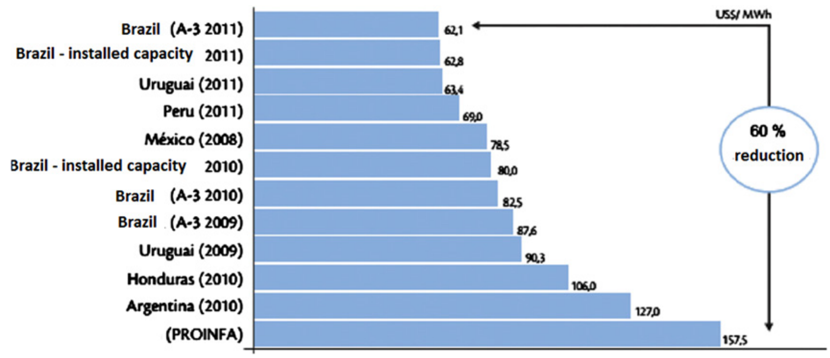


Fig. 2. Price of wind energy in Latin America.
Source: EPE [22].

guarantees are defined in the operation analysis. Currently, BNDES is the main source of funding for renewable resources in the country. In 2011, approved wind energy financing reached US$ 2 billion, which was an increase of 275% from 2010.

Under the aligned industrial policy, mandating local content to access funding attracts several suppliers for Brazil. The presence of these new manufacturers increases competition in the wind generation sector, which reduces the investment per MW of installed wind generation and decreases the cost of the produced energy. The result was observed in recent auctions for alternative and backup power. The price of electricity sold at the auctions represents an important contribution for promoting tariffs. Currently, 12 manufacturers are producing wind turbines in Brazil for Europeans, Americans, Argentines, and Brazilians. Thus, Brazil is self-sufficient regarding wind turbines and the equipment used on wind farms.

The consolidation of renewable energy, particularly in relation to wind energy, is crucial for the continuity of long-term financing. This financing supports the energy sector and the industrial mesh sector, including industry capital from goods, which supports a potentially promising technology.

Regarding social aspects, the intensification of local conflicts as wind energy assumes more importance in the supply of electricity are not expected. This aspect provides bucolic appeal and assumes a major investment position to mold business groups. According to Slattery, Lantz & Johnson [24], the socio-environmental variables are multifaceted. The impacts of wind projects depend on their scope, the exploited resources and the participation of local entities (interested companies). In addition, the territorial scope of the project and the displacement of capital goods (e.g., blades and towers) directly impact the perceived impact of the local community. In extreme cases, the enterprise can generate few benefits for the local community.

Currently, social conflicts are observed in the Caetité (Bahia), Trairi (Ceará) and Galinhos (Rio Grande do Norte) regions. The production of energy with wind explains several contradictions that are inherent in capitalism and reduces greenhouse gas emissions. In contrast, wind energy leads to local land issues due to the misappropriation of land areas for collective use and the co-optation of local government entities. However, despite the creation of local jobs and mandatory transfers to local investments, the local economy dynamics support low-skill jobs and, in some cases, no formal employment (without contract). In addition, local social conflicts are an obstacle for promoting wind power. However, there is little space for the dissemination of these issues. Social acceptance of wind power has not been properly addressed by environmental licensing agencies (i.e., the implementation of these parks is not carried out with active participation from the community). This question is critical for the strong growth of the wind energy sector in the country in the years to come.

Social acceptance is characterized by socio-political, market, and community acceptance. Acceptance by consumers or investors (market acceptance) is easily observed from recent expansion and the growth outlook. The socio-political acceptance (technologies, decision makers, government) is observed and highlights the efforts by structuring the market and industrial policy. However, insufficient efforts have been made to promote community acceptance (Justice, local community). This study highlights the scarcity of research in this area, particularly in the area of renewable energy sources. In this case, community acceptance refers to the acceptance of specific energy projects by residents, local authorities and stakeholders. This question goes beyond simplifying NIMBY (not in my backyard). Wolsink [25] defines NIMBY as a situation in which people maintain a positive outlook regarding an issue until they are directly confronted with it, which creates a backlash of opposition.

According to Sworfford and Slattery [26], the definition of NIMBY in the literature varies. Wolsink [25] uses NYMBY as an explanatory factor for the perception of the population regarding wind power and has been heavily criticized in recent studies. These studies noted that Wolsink's concept failed to reflect the complexity of human motives and their interactions regarding political and social institutions.

Some specific actions for understanding local dynamics and acceptance were incipiently developed in Brazil. Recently, studies have sought to identify and assess the environmental licensing procedures of projects that are aimed at generating electricity from wind energy. The Ministry of Environment [27] surveyed 20 wind projects across Brazil. Based on this survey, we determined that several areas with good wind potential that are less susceptible to the environmental and social impacts of wind generation should be identified. This identification would allow security agent licensors to make decisions that support entrepreneurs in the planning and project design phases. Together, wind farms are often installed in areas that are protected by environmental legislation or have characteristics that could be exploited by other sectors of the economy, such as tourism. In this context, activities should be regulated. These regulations should clearly define rules to mediate any conflicts. Although such actions do not resolve all issues (such as the land issue in Brazil), they seek to minimize the environmental impacts of the site and to minimize the risk of the entrepreneur.

Lack of knowledge and confidence in the potential for renewable energy development should also be discussed. For a technology to be successful and widely used, it must be accepted at a local level. The association of non-energy benefits, such as increased income or the creation of local jobs, can help gain acceptance and promote the diffusion of new technology. Cooperative participation can be a tool for involving local communities in the development of renewable energy. Local and regional energy agencies are searching for ways to promote renewable resources and to inform, educate and train local communities that

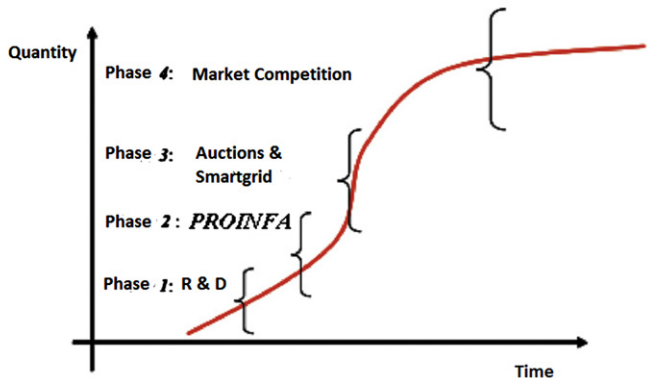


Fig. 3. Schematic model of wind energy development stages and incentive instruments in Brazil.
Source: Author's calculations based on Dutra [28].

seek to improve the acceptance of renewable resources. This promotion of renewable resources will enable a better dialogue between businesses and the local community. Currently, this dialogue is conducted at public hearings. However, this process needs to be improved, particularly for corporate goals that benefit the population after the construction phase.

The lack of a proper legal framework for supporting the development of renewable resources is of central concern in the literature. Regarding guaranteed access to the grid, mainly logistical costs are greater, which concerns small independent producers. In addition, the generation of electric power is often interrupted. The dispatch of wind power in Brazil is only guaranteed during favorable wind conditions. Electrical connections are supplied by the distributors and are integrated with the Brazilian electrical system.

Numerous obstacles occur in the research, development and demonstration stages. To reach full commercialization of the new technology, it is important that the industry is prepared to support the renewable resource goals. Unlike the European and American markets, which have strong planning, research promotion and wind industry development, initial market concerns occur in Brazil. However, despite specific university and research initiatives that were prompted by public resources, these technologies were not able to compete with large multinational companies.

The encouragement of some niche markets for new technologies through incentives and public investments is one of the most effective ways that the government has provided learning opportunities. These investments are recovering as the new technologies are maturing. The time frame of this split is a few decades, which requires long-term stable energy and technology policies. An incentive not to use these technologies can jeopardize their future success and limit their chances of future market penetration. Currently, the government is promoting research, development and innovation through public funds (Sector Funds). In addition, the government is funding pilot plants through FINEP (Research and Projects Financing) and strengthening research centers and universities that study renewable energy.

Since assuming Latin American leadership in 2012, Brazil is moving toward the consolidation of its wind energy market. However, considerable room for growth and technological development remains. As shown in Fig. 3, the technological development of wind energy in Brazil was conducted in three distinct phases over time as the country progressed. In each of these phases, specific policies were adopted to obtain the maturity that is necessary to compete with conventional electricity sources.

Typically, the first technological development phase is characterized by actions that stimulate innovation. Once the technology associated with the alternative source in question presents itself and is still in its infancy, its development should be encouraged by implementing R & D policies, subsidy policies or technological policies to ensure the development of specific market niches. These policies should provide a favorable environment for technological development and provide the technology with a more mature and competitive edge. However, R & D policy shares have become less necessary [28]. Brazil's efforts in this direction were limited and obtained few results for wind energy.

After the maturity stage or at the competitive threshold, government actions must focus on policies that provide competitive operations. The second phase aims to introduce the technology to a more competitive market. Because this is the technology's first contact with the competitive market, the technology should be supported by mechanisms that present a security level and provide development continuity in the competitive environment. In Brazil, instruments were used for specific auctions (PROINFA) to enable regulatory and financial stability for investors. The guarantee given on the energy purchases for a given period and the differentiation and pricing of each technology are important advantages for their continued technological development in the competitive environment.

After the development period and during the second phase, the technology tends to expand, which promotes a price drop and the continued maturation of the technology. In the third phase, the degree of technology maturation allows it to compete with other alternative technologies without maintaining specific market niches. However, recently, Brazil used auctions among energy sources, which exposed wind energy competition among the other technologies. Collectively, wind energy was regulated by the Smart Grid Regulatory Agency (ANEEL), which enabled easy access to small generators of up to 1 MW of installed power generation and subsidized connected charges. Individuals and small businesses can install micro generation systems of up to 100 kW and 101 kW and 1 MW in mini generation and can "sell" the excess power for use through the receipt of a claim. Other than this incentive, a discount of 80% of the connection fee will be provided for 10 years of connection.

Although the potential for micro generation was estimated in Brazil, its potential is enormous considering that the consumer rates are the highest in the world. In contrast, a plethora of resources can be exploited beyond wind by using small wind turbines for solar concentration technologies, biomass generation from municipal solid wastes, sewage or agricultural wastes, and other technologies that are still in their experimental stages. Micro wind energy opens a new frontier market and expands electricity access to remote areas in the country. In addition, micro wind energy decentralizes the generation of electricity in urban centers and enables significant environmental gains.

The fourth phase is characterized by the maturation of the technology to the point that it no longer requires specific policy for development. For conventional energy sources, the market dictates the rules. Because this market is mature, it can participate in more competitive markets without government intervention or specific policies. The wind energy segment in Brazil is in a transition phase between the third and fourth phases. Thus, additional government support is no longer needed.

7. Conclusions

The development of energy supply technology demands beyond the technical and economic aspects provides information regarding how to structure the generator matrix of such a demand. Thus, we examined the relationships that give impetus to the current style of development and concluded that these relationships were

structured to appeal wasteful consumption. As a natural response, this style of development continually expands the market needs, establishes progressive expansion of natural resource use, and determines the importance of successively searching for ways to expand energy availability.

Accordingly, we evaluated the proposed expansion of renewable resource use to meet the energy supply demanded by the goods production model based on the current development method. Thus, it is important to include the real Aeolian-electric technology in market dynamic debate. In addition, it is important to include rightful potential benefits to preserve the environment and to adjust the economic systems function.

Prior to the 1970s, the method of expanding Brazil's electrical industry was not significantly different than that used by the rest of the world. Brazil's method was regulated by increasing installed electrical generation capacities. This model exhibited flaws that reflected the adoption of new variables for consideration in the power energy sector. These variables included (i) the products of the economic, institutional, and technological variables; (ii) the instability of petroleum-based fuel prices following the 1973 crisis; and (iii) the prestige achieved by the environmentalist criticisms regarding the effects of the model against the natural environment.

In addition, the model began to weaken when research and development of renewable technologies began (especially for wind power). In this context, the structure of a favorable market for the expansion of Aeolian-electric technology requires the following:

- more flexible methods of evaluating technical–financial feasibility guided by the strict market logic;
- legal instruments and institutional arrangements that are clearly defined to develop basic sustainability conditions for the new market;
- the adoption of actions that make the power sector expansion planning culture flexible with conventional technologies; and
- environmental externality considerations of the conventional energy market to add value to the environmental benefits that arise from wind energy.

In addition, we could verify the commercial exploitation of wind energy in Brazil that was gained from the unsatisfactory results that occurred when it opened in the electricity market. The elements for attracting investor attention and for taking advantage of the high wind potential in Brazil are credited to the following (among others): (i) the strengthening of a national electricity supply crisis; (ii) the environmental attractiveness of renewable resources in comparison with the effects of fossil fuels, especially regarding global warming; (iii) the adoption of government programs to encourage the use of renewable resources; and (iv) the actions aimed at structuring a regulatory framework to include renewable resources.

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